REMARKS/ARGUMENTS

Claims 3, 6, 8, 12, 15 and 17 have been allowed.

Claims 1, 2, 4, 5, 7, 9-11, 13, 14 and 16 stand rejected under 35 USC 112.

Independent claims 1, 9 and 10 stand rejected under 35 USC 103(a).

Independent claims 1, 9 and 10 have been cancelled and replaced by (rewritten as) independent claims 18, 19 and 20, respectively. The scope of these claims remains the same but the wording has been clarified in view of objections raised in the office action. In claims 18, 19 and 20, the three stages, radio frequency conversion, common pre-processing and signal processing, are introduced in that order at the beginning of each claim and more-specific features of the common pre-processing and signal processing presented later in the claim. This is intended to make it easier to construe the claim wording and, in the process, clarify the differences between the present invention and the cited references.

The amendments to the DISCLOSURE OF INVENTION section of the Description align the three statements of invention with new claims 18, 19 and 20, respectively, and other amendments are explained hereinafter or are self-evident.

Regarding paragraphs 1 and 2 of the office action:

Claims 1, 2, 4, 5, 7, 9-11, 13, 14 and 16 were rejected under 35 USC 112, para. 1 as "failing to comply with the enablement requirement" on the grounds that the limitation "L is the maximum of the channel impulse response in symbol period *(sic)*" was not described in the specification "in such a way as to enable one skilled in the art ... to make and use the invention".

The term "L" is used by those skilled in this art to represent a physical characteristic of the channel. (The meaning of "channel" is defined on page 33, lines 31 and 32 of applicant's original specification). The term "L" was used in this manner at the following places in the original PCT specification:

page 4, lines 20 and 21; Page 11, line 25; Page 17, lines 15 - 24;

page 18, lines 1 - 11; page 21, line 28 - Equation (17).

The skilled addressee would know that the channels have an effective impulse response length of L times the symbol period (or taps of the equalizer). Consequently, the introduction of the variable L in claim 1, strictly for the purpose of expressing the number of space-time dimensions NxL of a fully adaptive receiver adequate for such channels, simply makes explicit

what was implicit to a person of ordinary skill in this art, namely that such a receiver would require the continuous adaptation of NxL taps. In view of the examiner's objection, however, and for greater clarity, the reference to symbol period in the paragraph beginning at page 11, line 21 of the original (PCT) specification has been expanded using wording similar to that used in claim 18 (prev. 1) and the term "L" has been inserted in the paragraph beginning on page 15, line 9. No subject matter has been added by this amendment since a person skilled in this art would have known this.

For consistency between the claims and the description, the term "R dimensions" in the claims has been replaced by the term "μ dimensions" which was used in the description (cf. original page 15, line 24). Also, in claim 7, "characteristics" has been changed to "signatures" for consistency with page 21, lines 24-26 of the original PCT application.

Regarding paragraphs 3 and 4:

The rejection of claims 1 (now 18), 9 (now 20) and 10 (now 21) under 35 USC 103(a) as unpatentable over Li *et al.* (US2004/0146024) and Li *et al.* (US6,795,392) is respectfully traversed for the reasons set out below.

The first part of paragraph 4 of the office action states that the receiver of Li '024 "has a common preprocessing section for sampling each of the antenna element signals *as claimed* (see Fig. 2 regarding input signals i[n] from M antennas and [0022] regarding sampled process)" *(emphasis added)*. In fact, <u>as claimed</u> in claim 18 preprocessing section (40) comprises

> filtering means (40/1, ..., 40/M) for sampling each of the (N) antenna element signals (x_1, x_2,..., x_N) and combining resulting samples of at least some of said antenna element signals to provide said plurality of (M+1) basis signals (y_0..., y_M),
>
> each of the basis signals (y_0,..., y_M) comprising a different combination of the antenna signals and having μ dimensions spanning a dominant subspace matched to the channel of a respective one of the transmitted user signals,
>
> said (M+1) basis signals together having fewer space-time dimensions (μx(M+1)) than the space-time dimensions (NxL) of the (N) combined antenna signals, where L is the length of the channel impulse response in symbol periods and
>
> updating means for periodically updating parameters of the filtering means (40/1, ..., 40/M) used for deriving each particular basis signal such that each of the user-specific estimated received signals (z_0, z_1,... z_M) will exhibit a desired optimized concentration of energy;

The sampling mentioned in paragraph [0022] of Li '024 is "analog-to-digital conversion and sampling" (line 2). It is equivalent to the "bandpass sampling" carried out in box **34/N** of Applicant's FIG. 1, which, along with analogue-to-digital conversion, is performed by Applicant's RF FRONT END 26/N) to produce the digital signals x1,..., xN which are inputted to the common preprocessing section 40, not carried out in it.

It is apparent from paragraph [0022] of Li '024 that the resulting digital signal is r_m, the "received (NQ+L)x1) uplink discrete-time traffic signal vector for mth base-station antenna". This not a "basis signal" as defined in applicant's claim 18. In so far as it corresponds to any of Applicant's signals, it corresponds to one of the antenna element signals *x1, ..., xN* which are inputted to the common preprocessing unit (40), not outputted from it.

In the second part of paragraph 4, the office action seemingly equates the Applicant's claimed common preprocessing section 40 to the entire receive chain in Li '024 up to the inputs of the joint detectors 214, to which the "output signals d[n]" of Li '024 are supplied. The office action actually states (with clerical errors intact)

> "a common processing for sampling each of antenna element signal and processing samples of at least some of said antenna signals together having fewer space-time dimensions (RxM) than the space-time dimensions (NxL) of the combined antenna signals, where L is the maximum of channel impulse response in symbol period (see Fig. 2 regarding output signals d[n], see Fig. 3 and [0020, 29] regarding space-time dimension with L is the maximum of channel impulse response in symbol period (sic))".

This is simply incorrect. In Li '024, the output signals **d**[n] are **not** basis signals as defined in applicant's claim 18. First of all, the term "L" in Li '024 is NOT the length of the impulse response in symbol periods as implied by the office action, but rather is used by Li '024 to refer to the number of resolvable paths in such impulse response.

A person skilled in this art would understand, based on common general knowledge, that basis signals correspond to vectors that span a space within a function space. Filtering means 40/0 of the common preprocessing section in Applicant's Figure 1, for example, produces μ basis signals, contained in vector $\mathbf{y}_0$, which correspond to μ orthogonal vectors capturing most of user 0's energy; hence the term "dominant subspace." (See definition on page 33). Hence, the processing performed by filtering means 40/0 is based strictly on the structure of user 0's

channel, and the interference from other users is totally ignored. The dominant subspace filters 40/0, ..., 40/M of the common preprocessing section 40 are used simply to intelligently reduce the number of dimensions before processing in subsequent interference nulling operations based on the space-time structure of user 0's channel. (see claim 18: "…spanning a dominant subspace containing most of the energy for a..."). In other words, within the NxL dimension space spanned by user 0's channel there is a subspace of μ dimensions (where μ is much smaller than NxL) which contains most of user 0's energy.

To make this distinction clearer, the wording of claim 18 now defines the nature of the basis signals as "... spanning a subspace containing most of the energy from one of the received signals, said (M+1) basis signals….

Moreover, because, in claim 18, the clauses of cancelled claim 1 have been re-arranged to bring all of the sections relating to the common preprocessing section together, it should be clear to a person skilled in this art that the function of the Applicant's preprocessing section 40 is to reduce the number of dimensions of the signals to be processed subsequently in a manner that minimizes performance loss by concentrating the useful energy into fewer dimensions; and this applies for <u>a given number of antennas</u> and transmitting users.

To summarize:

1. Li '024's signals **d**[n] are not basis signals spanning a subspace.
2. They do not have μ dimensions, i.e., there is only one signal per user, per carrier.
3. They do not have fewer dimensions than the space-time dimensions of the combined antenna signals since there are a lot more users than antennas in a CDMA system, and L is interpreted differently (it corresponds to the number of resolvable paths in Li '024, i.e., the channel order, and to the impulse response length or equivalently the tapped-delay line length in a conventional equalizer in the present application). Furthermore, temporal processing is simply not performed in Li '024 since the L paths are just added up in the spatial combining step.
4. The "preprocessing" in Li '024 performs filtering per carrier and per code (code correlators, i.e. despreading) prior to producing the **d**[n]. This results in a completely different context where, in fact, the users are pre-separated by virtue of their code, i.e. they are effectively on different channels in code space. This is not the case in embodiments of the present invention.

The third part of paragraph 4 equates the signal processing units (60/0 ... 60/M) of the present invention to joint detectors 214 in Fig. 2 of Li '024. With all due respect, this is not

acceptable and appears to be based upon misinterpretation of both Li '024 and claim 1 (now 18). The applicant's signal processors (60/0 ... 60/M) are not joint detectors, in that each works in isolation and detects a single signal, without using any explicit information from other detected signals. Nothing in new claim 18 suggests any form of joint detection. Moreover, in Li '024, the inputs to the joint detectors are not basis signals; as already mentioned, they are very nearly detected signals, having already gone through two stages of interference suppression. These are then processed to extract multiple detected signals jointly, which is a very high complexity operation. In contrast, the present invention is concerned with reducing complexity by reducing the number of (basis) signals to be processed.

Moreover, in the third paragraph, the office action states that Li '024 discloses "a plurality of signal processing units (joint detectors JD) each having a plurality of inputs coupled to the common preprocessing section for receiving all of the basis signals, each processing and combining said basis signals to produce a respective one of a set of estimated received signals each for a corresponding desired one of the users (see Fig. 4 regarding output signals S[n] and [0048 - 0064]." This is not correct for the following reasons:

(a) The described signal processing units are not joint detectors as such since they do not perform joint processing as in Li '024 where successive interference cancellation is performed. (In fact, the signal processing units 60/0, ..., 60/M Figure 1 of the present application are closer in function to the spatial combining blocks (212 in Fig. 2) of Li '024, which the office action has already assigned to common preprocessing.) The joint detection step is simply not performed and not necessary in embodiments of the claimed invention which targets contexts with fewer users.

(b) It would also not be viable to try to map the code correlator outputs to the basis functions in the present application because there is one code correlator output per antenna, per user, and per carrier in Li '024, while the claimed invention presents rather μ outputs per user, and the said outputs are meant to span a subspace of maximal energy.

(c) Another important difference is that Li '024's code correlators are matched to the user codes, while the dominant subspace filters of claim 18 are matched to the user channels. Also, each dominant subspace filter processes information from all antenna elements jointly, while the code correlators work on antenna element signals individually.

(d) The dominant subspace filters are NOT spatial combiners (as in Li' 024) since they

perform neither interference nulling nor SINR maximization.

It follows that, contrary to the assertion in the office action, the signals **d**[n] in Li ’024 do not constitute basis signals as defined in claim 18. In fact, they are already "received" signals, having gone through two steps of interference suppression (despreading and spatial combining). Conventional CDMA receivers would use the d[n] as the final received signals, as Fig. 1 illustrates, but Li ’024 adds another step of residual interference suppression with the joint detectors.

If one were to try using the basis signals x_1, ..., x_N of applicant's claim 18 in place of the signals **d**[n] of Li '024, i.e., directly as received signals, the receiver of Li '024 would not work since no interference suppression is performed at that stage, and separation of multiple, superimposed, co-channel signals, as taught by the present invention, would not be achieved.

In the fourth part of paragraph 4, the office action refers to the common preprocessing section once again. The recitation of the asserted elements of Li '024 is rather confusing but the reference to "output signal S[i], Fig. 3 and [0038 - 0045] appears to be asserting equivalence between the common preprocessor section 40 of the present invention and Li's joint detectors 214, since it is the latter that output the signals S[i]; yet the spatial combining and joint detection functions of Fig. 3 of Li '024 are prior to the joint detection.

Paragraph [0038] states that "FIG. 3 illustrates the details of the functional block 210 of FIG. 2. Using the joint channel response from each antenna 302, the spatial signature estimation is done in the functional block 304, and the spatial weight computations are further completed in block 306 based on each terminal's spatial signature and covariance matrix of interference and noise for the sub-carrier of interest." (It is noted that the caption to FIG. 3 reads "Spatial Weight Computation and Joint Detection Matrices Formation"). As explained above, this is simply not relevant to the common preprocessing section 40 of the present invention.

In addition, Fig. 3 relates to the parameter estimation functions, not the filtering means themselves. And again, the signals **d**[i] are not basis functions since they do not correspond to a linear vector in the space spanned by antenna element signals, having first gone through code correlators, and they are not generated according to any subspace structure in the channels.

The processing and combining techniques described in Li '024's paragraphs [0038—0045] are well known and constitute textbook material. Likewise, the processing depicted to compute vectors w in Fig. 3 is standard practice. These known techniques are not the same as the

processing set out in claim 18, in which the signal processing is carried out after the pre-processing section has reduced the space-time dimensions, thus dividing up the processing load between the two sections in a manner which yields complexity reductions.

In the fifth part of paragraph 4, the office action equates the updating means of claim 1 (now 18) with Li '024's general discussion in paragraphs [0033 - 0048], noting specifically the term "maximum signal energy" in paragraph [0038]. Once again, there is simply no such equivalence or correspondence. Paragraphs [0038 - 0048] discuss the processing involved in the spatial signature in Li '024 and have no relevance whatsoever to the dominant subspace filtering's function of "maximizing desired signal energy." The concept of maximum signal energy drawn from Li '024 in paragraph [0038] pertains to the spatial signature (a well known textbook concept) which corresponds to the spatial direction of "maximum energy." While this concept is one particular case of the "subspace of highest energy" in embodiments of the present invention, Li '024 does NOT use it directly as a filter to produce a basis function, but rather as a component in the computation of weights, which is totally different.

In embodiments of the present invention, the common preprocessing section 40 provides much of the performance of a fully-adaptive NxL dimension receiver at a significant complexity advantage, by "intelligently" reducing the number of dimensions of the signals which are to be processed subsequently. Indeed, the common preprocessing section 40 transforms the input into a domain where the useful information is concentrated in fewer dimensions, so that many dimensions can be dropped without affecting performance too much. This applies regardless of the number of antennas as compared with the number of users. There is no suggestion of such an approach in either Li '024 or Li '392 and a person of ordinary skill in this art would have no reason to try combining them to solve the problem addressed by the present invention in the manner claimed in new claim 18. Indeed, even if the skilled person were to combine Li '024 and Li '392, the end result would not be the claimed invention because so many features of claim 18 are not disclosed by Li '024, as discussed above, and Li '392 does not make up the deficiencies.

With respect to paragraph 6 of the office action, the examiner claims that Li '392 teaches that the number of antennas can be more or less regardless of the number of users. However, Li '392 is concerned with users coexisting on different clusters of carriers, while Li '024 is concerned with users on different codes and/or carriers. Claim 18 now specifies "co-channel transmitting users" since, as should be clear to someone skilled in this art, the present invention

is concerned with co-channel users, e.g. users transmitting on the same channel at the same time, where the spatial processing made possible by an antenna array constitutes the exclusive means of separating the users. In such a case, the number of antennas MUST be equal to or greater than the number of transmitting users. The problem that the present invention addresses is that of separating multiple co-channel users with minimal implementation complexity. Neither Li '024 nor Li '392 addresses this problem, since the user signals in their case (CDMA context in Li '024, clustered OFDM context in Li '392) are separable without resorting to array processing. Antenna array processing in Li '024 and Li '392 is simply an added feature to further improve the SINR at the price of INCREASED complexity with respect to a conventional receiver. Therefore, not only is the addressed problem different, the cost-complexity trade-off is the exact opposite.

While the present application mentions the possibility of usage in a CDMA context, it is specifically stated that it would then be used strictly to separate users that coexist on the same code or are otherwise impossible to separate without resorting to spatial processing, in which case, the number of antennas would necessarily be higher than or equal to the number of users in the said subset.

Another distinction is that user signals exist in different vector or signal spaces in both Li '024 and Li '392 (since they are on different channels), while they exist in the <u>same vector space</u> at the input of the receiver of claim 18 and are therefore more difficult to separate. Since this vector space has a high number of dimensions, the inventor proposes a means to reduce said number to simplify processing. The inventor has established that the total number of dimensions to process in this case is N x L and that (M+1) x μ would constitute a smaller number of dimensions. M antennas > N users is not a feature of the invention; it is the context where the invention provides the best complexity benefit.

In Li '024, the total number of signals to process is given at the output of the code correlators (using our notation) N antennas x M users x P carriers. This is the natural space of that particular problem, and Li '024 performs no reduction of this number of dimensions.

In view of the foregoing, it is submitted that claim 18 is patentable over Li '024 and Li '392 whether taken individually or in combination.

Claims 19 and 20 are, respectively, a system claim and a method claim corresponding to claim 18 and patentable for the same reasons.

The dependent claims include all of the features of one or other of claims 18, 19 and 20

and so are patentable by virtue of such dependencies, notwithstanding the fact that the dependent claims introduce features which result in novel and non-obvious combinations.

Accordingly, it is submitted that all claims of record are patentable and early and favourable reconsideration of the application is respectfully requested.

Respectfully submitted

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